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INTRODUCTION

(Muhammad Nabeel Musharraf)

We are very pleased to present the second issue of **Australian Journal of Engineering and Technology Research.** Following is a brief overview of our journal, its purpose and current issue.

AJETR is a multi-disciplinary and open-access publication launched with an aim to encourage and facilitate the original research with a particular focus on developing countries. Accordingly, all publication fees are waived off for students from 28 different universities from these countries.

Our scope covers a broad range of engineering and technology related disciplines. Research papers, book reviews, thesis and other scholarly works can be submitted for review throughout the year. Each year, **AJETR** has planned to launch two issues.

We aim to go a step ahead of other journals in terms of our commitment to nurturing the future researchers. In order to further this aim, we will be more than pleased to guide, assist and train young researchers and help them pave their way into an exciting research career. We are also very keen to form partnerships with universities in order to provide them useful research support and train their young researchers.

I would like to extend my gratitude to all researchers, reviewers and others who supported Australian Research Journals in launching this research journal and presenting the current issue. We hope it comes out as a highly beneficial endeavour for the whole engineering and technology research community.

Yours Sincerely,

Muhammad Nabeel Musharraf

December 31, 2016

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SIMULATION STUDY OF WATER SHUT-OFF TREATMENT BY USING POLYMER GEL

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ABSTRACT

The wells' hydrocarbon productivity is affected by high water production which is produced along with the hydrocarbons. The complex reservoir changes during production, infiltrates water tables into the reservoir and ultimately affects the water production. The reduction of high water production is difficult in oil industry though of utmost importance as the water produed in the process damages the equipment mechanically and sometimes effects chemically, depending on the water composition.

This research study focuses using an appropriate chemical in the process i.e: Polymer gel treatment. The Colloidal Dispersion Gel (CDG) is injected into the reservoir via injection well. The well initially was noted to be high water-cut well. CDG increases the viscosity of water and decreases the mobility of water. The results show the water cut reduction of up to 23% (as initially the water cut was 78%). That is a significant reduction in the production of water, which ultimately save techno-economics and eventually the increment of oil would contribute towards meeting today's oil requirement of market resulting in higher profits.

Keywords: Colloidal Dispersion Gel (CDG), Wells, Water Production, Reservoir

1. INTRODUCTION

The mature oil fields produce heavy saline water which results in operational problems and increases water disposal cost [1].These problems are faced by injecting fluids which are used mostly to reduce the oil displacement channels, because of which the early breakthrough of water can affect the hydrocarbon productivity [2]. During recent years in oil industry, the production wells are placed on high production because the demand of oil is increasing day by day having no concern initially to water-cut, which eventually leads to high water-cut oil wells [3].

The high water cut in mature oil fields is of utmost importance that leads to huge techno-economics for treatment and disposal. The Polymer Gels which have been used for shut-off treatment helps blocking the pore spaces of water producing zones [4]. Wells which are being produced using water drive or being produced by water flooding methods lead to early water encroachment in the reservoir. This trend changes the prominent flowing stream of oil to water and affects the mechanical equipment and also creates water conning - the process known as hydrostatic loading

[5]. The polymer is being broadly used as water shut-off chemical in last two decades [6]. In mid-1980s, polymer and cross-linkers were used in petroleum industry and were known as CDG [7].

2. OBJECTIVES OF SHUT-OFF TREATMENT

This study investigated the use of CDG for flooding. It has been confirmed that the CDG is effective both technically and economically in the wells producing high water-cut. This method is focused on modeling the CDG injection in reservoir and is simulated using the software. Objectives of the study are as follows:

1. Simulation study of injecting CDG in oil well and simulation of results using commercial simulation software.

2. Comparison of oil reduction to water production using CDG.

3. RESULTS & DISCUSSIONS

The well which is used for simulation has rock characteristics as mentioned in Table 1 whereas fluid properties are mentioned in Table 2 and SCAL data is in Table 3.

Table 1: Rock Characteristics of the Well

Reservoir Geometry	Block centered
Number of cells in X direction	5
Number of cells in Y direction	5
Number of cells in Z direction	3
X Permeability,mD	200
Y Permeability,mD	150
Z Permeability,mD	20
Porosity,Percent	0.2
Depth,ft	8000

In this well initially water cut was up to 40 STB/D, which was increased as the time passed and after 3.3 years (1,200 days), the production of oil was 4,700 STB/D. At this stage, the water cut was a bit increased and its value was 47%. Water production was found to be increasing day by day and it was eventually noted to be at 78% which shows negligible hydrocarbon recovery. The simulation was done by injecting CDG at this stage which shows prominent results.

Table 2 Fluid Properties

Fluid Property	Value
Oil Density, lb/ft^3	49
Water density, lb/ft^3	63
Gas density, lb/ft^3	0.01

Table 3: SCAL Data

Sw	Krw	Kro	Pc
0.25	0.0	0.9	0.9
0.5	0.2	0.3	1.8
0.7	0.4	0.1	0.45
0.8	0.55	0.0	0.22

Figure 1 depicts Field Water Production Rate and Field Oil Production Rate.

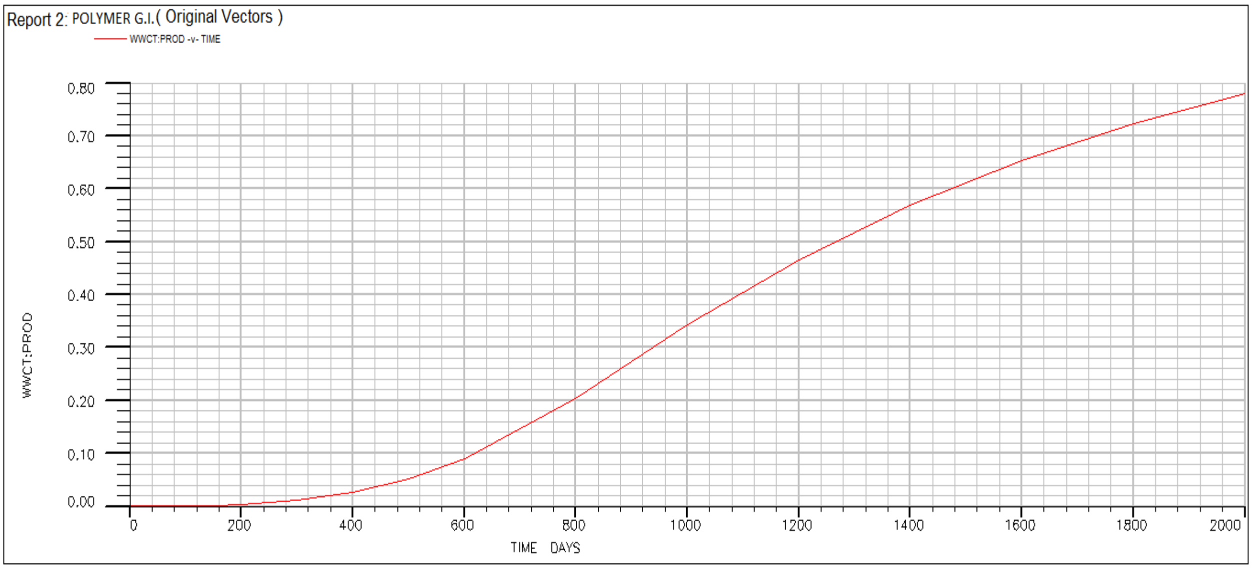

Figure 1: Water cut Production

After injecting CDG, the results have shown an increment in oil production (4,800 STB/D) and decrease in water production that was noted to be 6,600 STB/D at 2,800 days as shown in Figure 2.

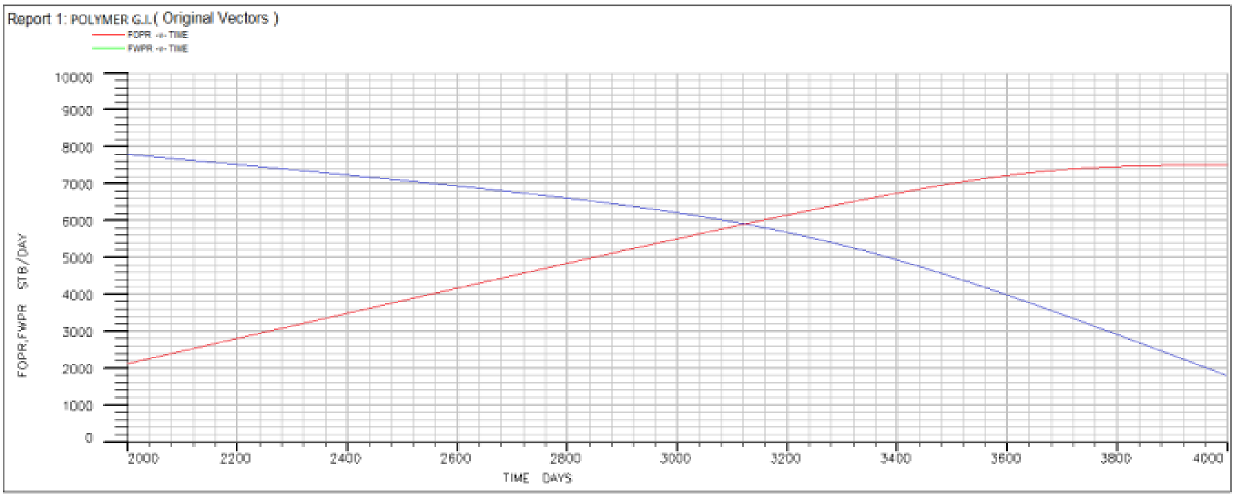

Figure 2: Oil-Water Production

Finally, the simulation showed that the water cut reduced from 78% (7,800 STB/D) to 56% (5,600 STB/D) and oil production incremented up to 6,150 STB/D after 3,200 days. As shown in Figure 2

4. CONCLUSIONS

It is observed in this study that the amount of water removal up to 3,200 days was 2,200 STB/D whereas; initially it was 7,800STB/D which can be continued depending on reservoir conditions.

This study's results showed that the water production was reduced by 21%. Likewise, CDG improved the prominent production of oil.

Based on this, we can recommend the use of CDG to overcome the problem of over-production of water and increasing the oil production.

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SIMULATING THE PRODUCTION STRATEGIES FOR OPTIMIZATION OF THE GAS RECOVERY FROM A WATER DRIVE DRY GAS RESERVOIR

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ABSTRACT

The water drive is the most economical natural drive mechanism. The recovery factor of water drive dry gas reservoir is about 45-70% when produced under conventional restricted approach. The reason for this is that the water encroaches into the gas zone and traps the gas. Hence, the production strategies such as the conventional approach, blow down approach and coproduction on a heterogeneous reservoir to optimize the gas production may be used. The co-production strategy has provided the good results with an encouraging recovery factor. It may be found to be more economically feasible in comparison to other production strategies.

INTRODUCTION

In Pakistan, the current gas supplies are over 4,000 MMCFD whereas the current market demand is more than 6,000 MMCFD as reported by Pakistan Economic survey 2014-2015. The main reason for difference in gas supply and demand is the continuously reducing supply of natural gas from the existing fields and the slow rate of new gas discoveries, which has shown a decline in the past decades [1].

The drive mechanism plays a vital role in hydrocarbons recovery. There are three main types of gas reservoirs i.e. Dry, Wet & Retrograde Condensate Gas Reservoir. All these types have different properties and recovery factors. The depletion or volumetric and water drive are the major drive mechanisms in the gas type reservoir. Almost 80-90% of gas recovery may be obtained from depletion drive whereas recovery factor is 70-80% for partial water drive and 50-60% for active water drive mechanism as reported in literature [2-4]

RECOVERY TECHNIQUE

Nowadays, many reliable techniques have been practiced for enhancing the Ultimate Gas Recovery (UGR) from the sources like Water drive dry gas reservoir (WDDGR) [5]. Following are the most

considerable techniques which have used for optimizing the gas recovery from WDDGR:

1. **Conventional Production:** By this technique, (i) the restrained flow rates are departed throughout the wells and (ii) the production aborts when wells are watered-out.
2. **Blow-down:** By this technique, withdrawal gas production rates are enhanced in order to outrun the aquifer advances that may result in a boosted UGR.
3. **3. Co-production:** By this techniques, UGR can be increased by producing water from downdip/edge wells. This technique is helpful in depletion of aquifer and gas volume.

RESEARCH METHODOLOGY

The Eclipse 100 – Black Oil Simulator is used in this study. Following procedural steps have been implemented:

- Definition of the study objectives.
- Model description and selection
- Collection of relevant reservoir data.
- Validation of the data.
- Reservoir model construction.
- Formulation of the running model and prediction cases.
- Simulation and result analysis.

MODEL WORKFLOW

The workflow for model description is defined as below (Fig.1.):

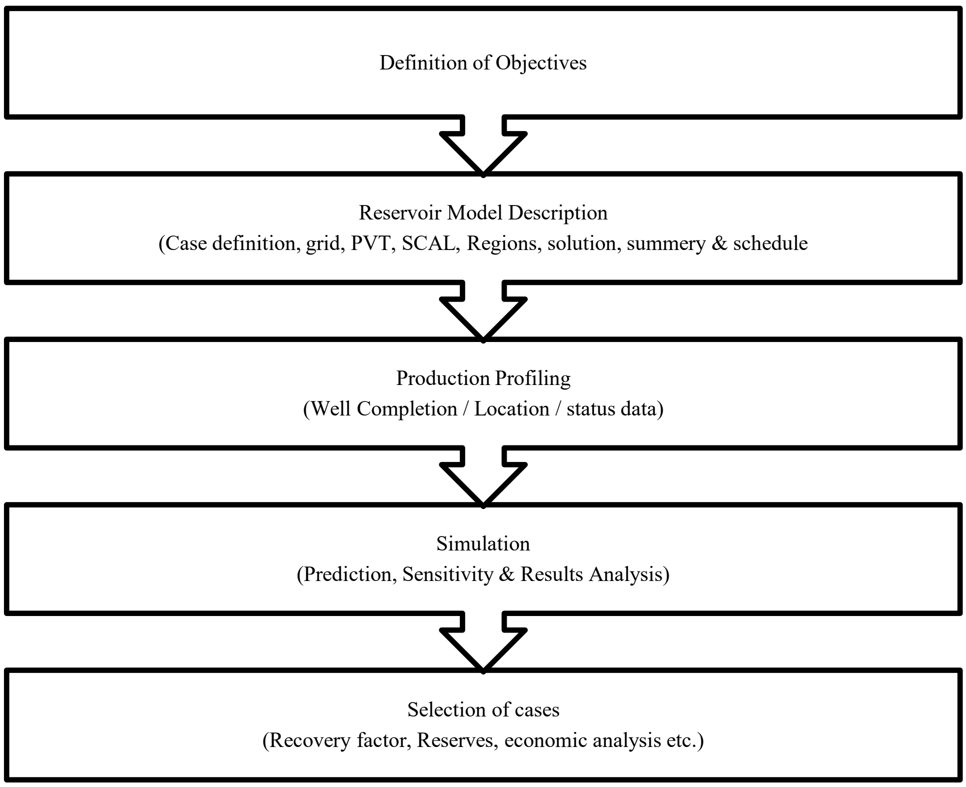

Figure 1: Model description workflow.

EFFECTS OF WATER DRIVE DRY GAS RESERVOIR ON ULTIMATE GAS RECOVERY

The stabilization pressure, mobility ratio, and aquifer size and production rates are all important parameters and have effects on the water drive dry gas reservoir.

The details of these effects are given below:

1. Effect of Stabilization Pressure

Through the volumetric recovery methods, the effect of pressure can easily be illustrated. For example, for any system, the gas saturation (Sg) is equivalent to the differentiation of initial gas saturation (Sgi) and the residual gas saturation (Sgr). But, to some extent, the amount of mobile gas saturation is captured by the overstep water in a WDDGR, called the trapped gas saturation.

It is further illustrated that Sgr is not dependent of pressure and may become a reason for greater recovery at the lower stabilization (abandonment) pressure. In case of higher stabilization pressure, the recovery will be smaller.

2. Mobility Ratio

Understanding the inimitable feature of the displacement of water in a gas reservoir is very vital. For that, practicable mobility (M) between the two fluids is to be considered. Basically, M is a ratio between the mobility of two fluids such as advancing fluid (i.e "Water" in case of WDDGR) and displaced fluid (i.e "Gas" in case of WDDGR).

For Darcy's law equation, mobility represents part of it and it is defined as a ratio between relative permeability to the viscosity of the given fluid. The movement of fluid depends upon the mobility of the fluids i.e a higher mobility will be a higher movement of fluid. For example, if M is 0.01:1 it would represent the water being an advancing fluid, travels 100 times slower than the gas or, in other words, the amount of gas being advanced is 100 times more rapid than water [6].

3. Aquifer size

The mass of aquifer is also of high importance and effects on UGR in any reservoir strategy and management approach. Bass Jr. and Al-Hashim conducted research on a homogeneous and radial type flow model and the findings of their research indicated that when $0 \le r_a / r_g < 2$, the aquifer effect on the gas reservoir's performance is negligible [7]. Aquifer effects the performance of a given reservoir when $r_a / r_g < 2$ as shown in table 1[8-9]. The Table 1 can be used to gauge the effect of production rate sensitization and aquifer size on performance.

Table 1: Effect of recovery sensitization and aquifer size on performance.

At r_a/r_g 1	**At r_a/r_g 4**
Effect: Negligible Sensitive rate: Not	Effect: Significant Sensitive rate: Significantly

At r_a/r_g 2 Effect: Minor Sensitive rate: Slightly	**At r_a/r_g 4** Effect: Significant Sensitive rate: Significantly
At r_a/r_g 3 Effect: Modest Sensitive rate: Moderately	**At r_a/r_g 6** Effect: High Sensitive rate: Highly

DATA GATHERING

For preparing the model for optimize gas recovery from WDDGR in Eclipse-100 black oil simulator, the following data had been taken from the "**X**" field'.

- Initial average pressure: 4927.87psia at a datum depth of 10745.76 feet.
- Reservoir volume: 932,933,085RB.
- Initial gas in place: 132 BCF.
- Initial water volume: 754.82 MMSTB.
- Gas water contact level at: 11161 feet.
- The reservoir is heterogeneous
- Region Averaged Grid Quantities
  PERMX = 185.38 md; PERMY = 185.38 md PERMZ = 34.34 md;
  PORO = 15.996% DZ = 63.875 ft
- Grid dimensions of the Reservoir-M

Direction	Locations of Grid	Grid average length in ft
X	14-25	658
Y	72-157	651
Z	109-114	10.97

- Grid description:

Model Dimensions	Grid Geometry	Grid Type
29 × 156 × 171	Cartesian	Corner Point

- Formation properties, Reservoir fluid properties, FVF and other relevant data are shown in table 2 to 5.

RESULT AND DISCUSSION

As discussed earlier field data and basic factors were used as input in a simulator which revealed the following results:

1. The simulation has been done from the period of 01-Jan-16 to 31 Dec, 2016 and achieved the successful results.
2. Field Gas Production is illustrated in Fig.2 and shows the gas production rate. Here the major point to note is that the gas production reached almost the same level, i.e 123000MSCF/D, on 1-Aug-2016 by blow down methods as well as the co-production technique. After that time, the gas production has decreased w.r.t time by blow down technique whereas it has increased when co-production technique is employed.
3. Fig.3 shows that the cumulative field gas production has 101363120MSCF/D by co-production technique as maximum (as compared with the blow down (i.e 88733176MSCF/D) and conventional (i.e 85823624MSCF/D) technique).
4. Fig.4 to Fig. 7 show the results with regards to field gas in-place, field gas pore volume and water production of conventional, blow down and co-production techniques.
5. Fig. 8 shows that the water advance is slow as co-production pressure is reduced in the water producing well. The overall pressure of the reservoir is reduced and the well static bottom hole pressure gets produced until the limiting tubing head pressure of 500 psi is achieved. Wells are shut due to pressure constraint and not due to High water gas ratios [10].

CONCLUSION

1. Co-production technique is observed to have played a vital role in producing the reserves at maximum rates, followed by blowdown and conventional technique.
2. Co-production technique demonstrated a greater impact in terms of techno-economic factors and relevant consideration as compared to other production strategies and techniques.
3. Intensity of the aquifer and well placement are both the prime point factors for an enhanced recovery. It is concluded that due to the excessive water cuts, the wells are shut in conventional and in blowdown technique whereas gas producers were shut due to the pressure reduction in co-production technique. Overall result is that the incremental reserves may be achieved better than blowdown technique.

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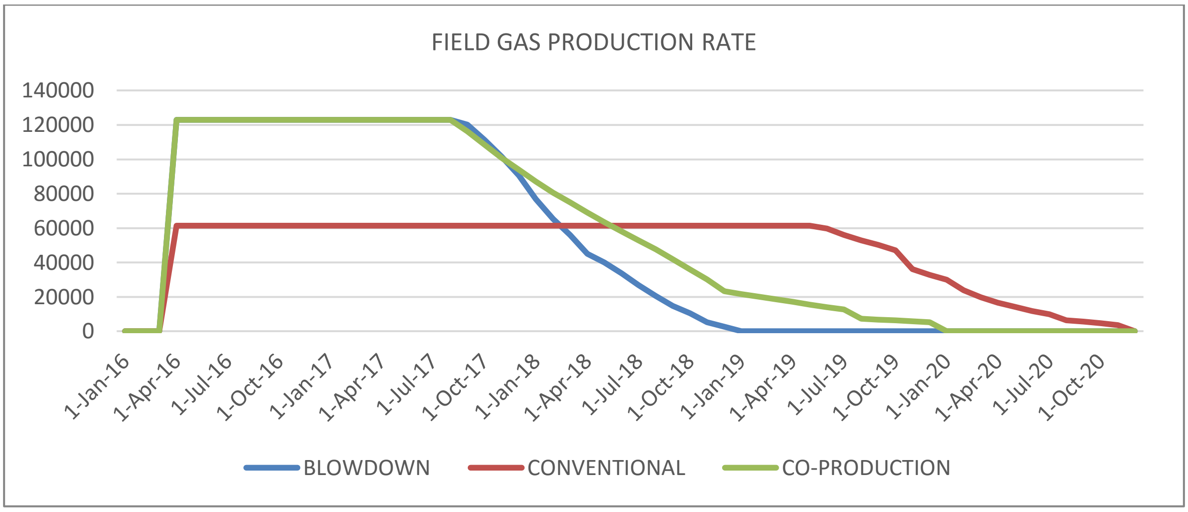

Figure 2: Field Gas Production Rate.

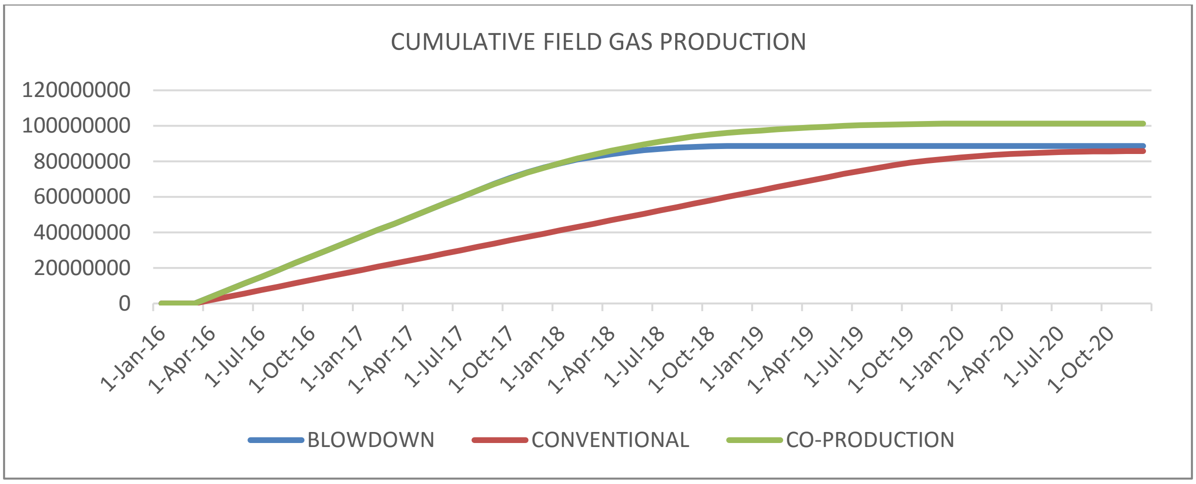

Figure 3: Cumulative Field Gas Production.

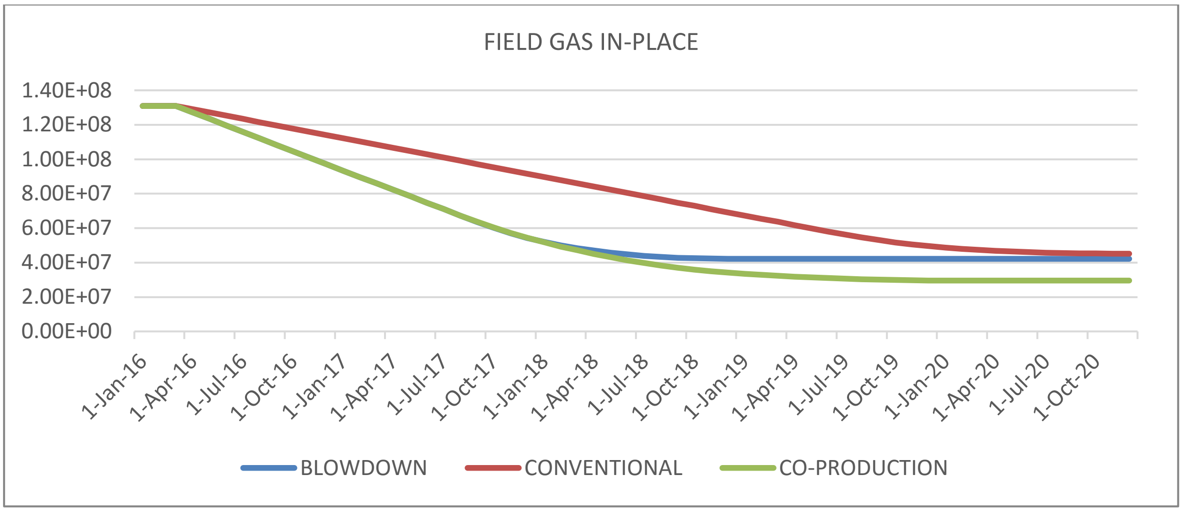

Figure 4. Field Gas In-Place.

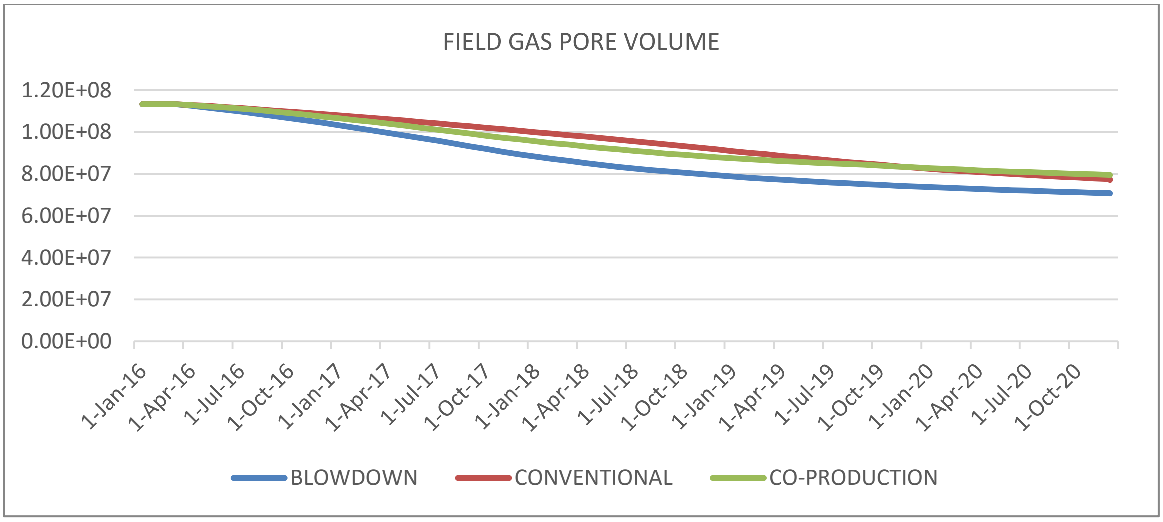

Figure 5: Field Gas Pore Volume.

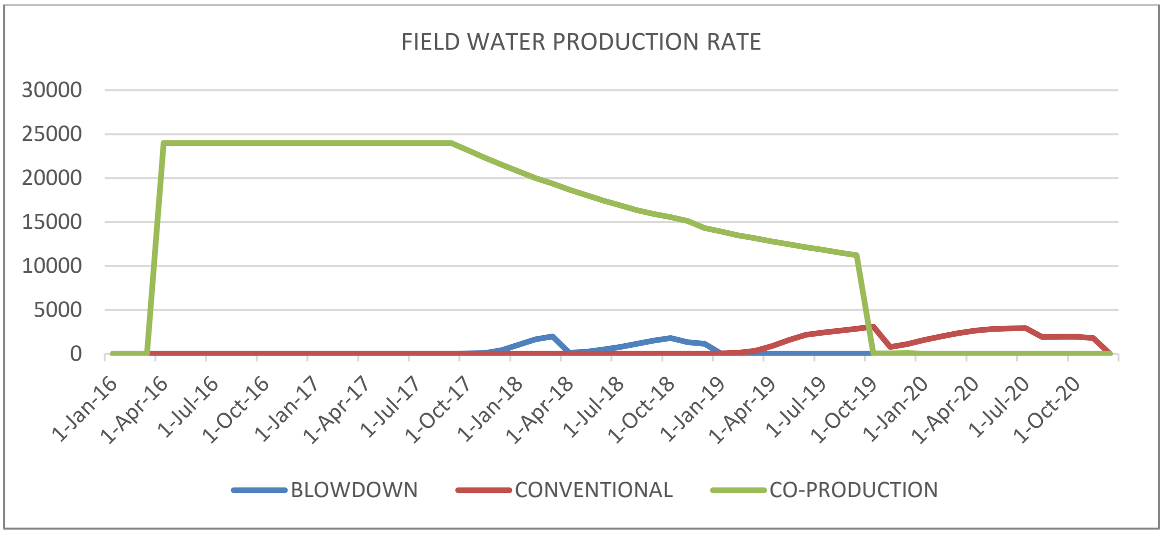

Figure 6: Field Water Production Rate.

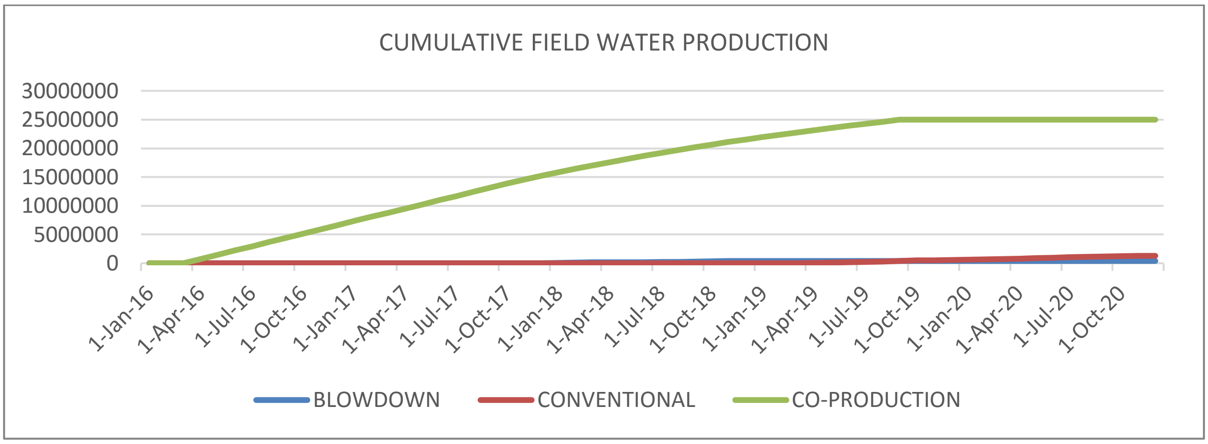

Figure 7: Cumulative Field Water Production.

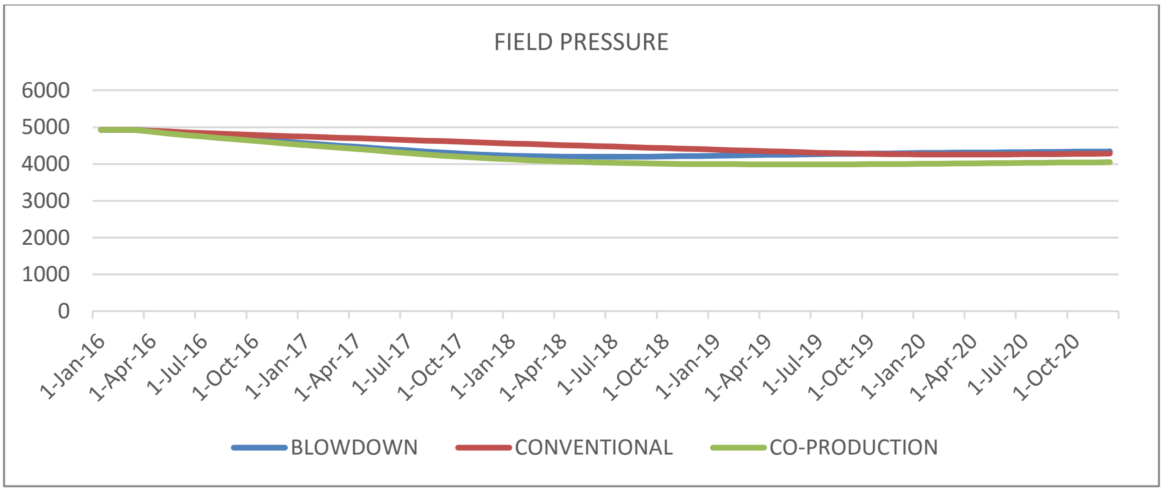

Figure 8: Field Pressure.

Table 2: Formation properties

Layer	Porosity	kx=ky (md)	kz (md)	Thickness
108	10% to 30%	0.1 to 1001	0.01 to 101	13.298 – 15.741
109		101 to 2001	10 to 201	10.433 – 12.576
110		11 to 1001	1 to 101	17.711 - 19.516
111		101 to 1001	10 to 101	14.069 - 15.356
Formation compressibility			1.808E-5 psi^{-1}	

Table 3: Reservoir Fluid Properties

Parameter	Set Value
Density of water	64.101 lb/ft^3
Density of gas	0.0507 lb/ft^3
FVF of water	1.088 RB/STB
Compressibility of water	4.3E-6 psi^{-1}
Viscosity	0.17 cp

Table 4: Gas FVF and gas as a function of Pressure.

Pressure value (psia)	Gas FVF(RB/Mscf)	Viscosity
16	270.511	0.014
501	7.891	0.0138
1001	3.937	0.0146
1501	2.619	0.0153
2001	1.960	0.0170
2501	1.586	0.0168
3001	1.337	0.0175
3501	1.159	0.0183
4001	1.034	0.0190
4501	0.927	0.0197
4869	0.873	0.0202
5001	0.855	0.0204
6001	0.730	0.0234

Table 5: FVF, compressibility and viscosity of water as a function of Pressure

Ref Pressure (psia)	Water FVF	Water Comp:	Water viscosity
4901	1.088	4.3E-6	0.17

A CASE STUDY OF THE PRODUCTION STRATEGIES OF FOUR WELLS FOR OPTIMIZINGN THE GAS RECOVERY FROM WATER DRIVE DRY GAS RESERVOIR

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ABSTRACT

Nowadays, many gas recovery techniques have been practiced in order to meet the current demand of market. Simultaneously producing gas and water from their respected zones is a viable production technique and provides additional benefits and maximizes the recovery as compared to conventional technique.

In this study, the important production strategies i.e (i) Conventional, (ii) Blowdown & (iii) Co-production are considered for evaluation and sensitivity analysis for a water drive dry-gas reservoir by using a field data simulation. The gas recovery target can be achieved by selecting the optimum production strategy resulting in the maximized reserves and improved recovery factor.

INTRODUCTION

The water drive dry gas reservoir (WDDGR) is one of the most economical drive methods. Many production techniques are to being used for enhancement of the recovery of gas from such type of drives. Among them, the co-production is a viable production technique and commonly used nowadays for optimizing the gas recovery from water drive dry gas reservoir. By the co-production technique, the 21% Ultimate gas recovery (UGR) has been improved in a Gulf-coast Eugene Island Reservoir [1]. Another study showed that predicted recovery of the field yielded 83% of Ultimate recovery factor (URF) as compared to 62% for conventional production [2].

LITERATURE REVIEW

Following is a brief overview of relevant literature.

Cohan (1989) inquired a bottom / edge water drive dry gas reservoir and found that the 'conventional wisdom' with regard to the production strategy may sometime needs to be modified according to conditions in the reservoir. He established that it is not necessary that accelerated production always yields more ultimate recovery [3].

McMullan et. al. (2000) investigated the effect of accelerated gas withdrawal rates and concluded that the elevated gas never harmfully impacts the UGR. In the lower permeability systems, accelerated gas withdrawal rates yielded significantly improved UGR [4].

Sech et. al. (2007) investigated the risks associated with the accelerated production in horizontal wells and suggested that in a bottom-water drive higher production rates via large-bore horizontal wells do not result in an enhanced URF. Despite this, there are many cases where accelerated production shows a little less URF but may be more economically favorable [5].

Stein et. al. (2009) presented various case studies and discussed various operating conditions. Conclusion of this study was that by using an Integrated Asset Modeling approach, gas field performance can be optimized and thereby it can result in increasing the reserves by enhancing gas production rates [6].

Rezaee et. al. (2013) determined that there is an optimum flow rates area, in a graph between gas flow rate and recovery factor (RF), which could yield the maximum recovery factors. This determination of optimization could be done on laboratory scale on reservoir sample rock for development of WDDGR [7].

Naderi et. al. (2014) worked on optimizing production from WDDGR based on desirability concept and concluded that accelerating gas production decreases URF by 3.2% to 8.4% because of poor Volumetric sweep efficiency and early water breakthrough, but it may be economically feasible if timescales are short. Further, increasing production rate from 60 to 120 MMSCF/D increases Gas RF by 8% [9].

Thomas (2005) suggested that ideally coproduction should begin simultaneously with gas production, which may need intentional drilling of water well in aquifer. Mostly it is preferred to turnaround the gas well into water wells once water has shut gas well's production [9].

CASE STUDY

In Sindh Province of Pakistan, the M-reservoir was found in Southern Mid Indus Platform Basin (known as Zone-III) as shown in Fig.1. The evaluation and a sensitivity analysis were done in this reservoir and various parameters were logged. After that, the best parameters for production strategy would be opted.

The following production strategies are used for evaluation and a sensitivity analysis for optimizing the gas recovery from WDDGR:

1. Conventional Production, 2. Blowdown, 3. Co-Production

Figure 1: Southern Mid Indus Platform Basin Zone-III (M-RESERVOIR).

RESERVOIR AND WELL DESCRIBTION

Reservoir has a keystone shape, three way dip and with is supported with the edge water drive. Four wells (W-1, W-2, W-3 & W-4) having 4.5 inch OD are located in A, B & C locations. W-1, W-2, W-3 are in gas zone while W-4 is in water zone.

EXPERIMENT CASES

Following three cases, as discussed in the literature review section, are constructed.

1. Conventional (Restricted) Low Rate Production Strategy / Technique
2. Blow-down (Out-running) Accelerated Production Strategy / Technique
3. Co-Production Strategy / Technique

The construction of experimental cases is discussed below: -

1. Conventional Restricted Technique

The construction of the Conventional (restricted) technique case with assumptions is discussed herewith.

i) **Flowrates:** Low rate production rate is taken - maximum of 20 MMSCF/D per well.
ii) **Wells:** Production is taken from three wells in the gas zone only.
iii) **Production Strategy:** Production time will continue until all gas wells are shut due to high water cut.
iv) Depletion of pressure will be slower, due to low rate of production and more production time.
v) There is a facility in place for gas processing.

2. Blow-down Technique

The construction of the Blow-down technique case with assumptions is discussed herewith.

i) **Flowrates**: Accelerated production rates are relied upon in this. Production rate of twice the conventional restricted approach are considered. A maximum gas production rate of 40 MMSCF/D per well is carried out.
ii) **Wells**: Production is taken from three wells, which are produced from the gas zone only.
iii) **Production Strategy**: Production time will continue until all gas wells are shut due to high water cut.
iv) Depletion of pressure will be faster, due to accelerated production rate and less production time.
v) There is no processing facility constraint.
vi) Market requirement is there and agreements are in-place.

3. Co-Production Technique

The construction of the Co-Production technique case with assumptions is discussed herewith.

i) **Flowrates**: Accelerated production rates are relied upon in this. Production rate of twice the conventional restricted approach and the same as in the blowdown approach is xonsidered. A maximum gas production rate of 40 MMSCF/D per well is carried out. This is done to compare this with the Blowdown approach. There is a water-well in the aquifer zone that produces at 25,000 STB/d.

ii) **Wells**: Gas Production is taken from 3 (three) wells, which are produced from the gas zone only. Simultaneously water production is carried out in order to deplete the reservoir pressure and retard the aquifer advance.

iii) **Production Strategy**: Production time will continue until all gas wells are shut due to lower limit of tubing head pressure which is set at 500 psi.

iv) Depletion of pressure will be faster, due to accelerated production rate and moderate production time.

v) There is no processing facility constraint.

vi) There is a water disposal well available.

vii) Market requirement is there and agreements are in-place.

All above cases are summarized in table 1:

Table 1: The development of cases.

Well	Pre-dominant Producing fluid	Maximum withdrawal rates along with status					
		Conventional Technique		**Blowdown Technique**		**Coproduction Technique**	
		Gas Production in MMSCF/D	status	Gas Production in MMSCF/D	Well status	Gas Production in MMSCF/D	Well status
W-1	Gas	20.00	Open	40.00	Open	40.00	Open
W-2							
W-3							
W-4	Water	00 MSTBD	Shut	00 MSTBD	Shut	25.00 MSTBd	

RESULT AND DISCUSSION

The following results have been concluded from this simulation study:

1. The gas production rate of all four wells (i.e W-1, W-2, W-3 & W-4) changed with respect to the production strategies.
2. The simulation results are illustrated from Fig.2 to 4. These results show the pressure behavior, gas saturation and water saturation at initial and final condition in all prescribed production strategies and will help in understanding the behavior of gas flow.
3. Gas Production rate of W-1, W-2, W-3 from well analysis are;
   (a) At constant rate of 20 MMSCF/D for a longer time from Conventional.
   (b) At constant rate of 40 MMSCF/D for shorter time from blowdown and co-production.
   (c) As certain time is passed, the pressure drop will be faster as the change of rate is greater due to depletion/production rate. The production summary of co-production deviates in three producing gas wells from that of blowdown. This may be logic when response of aquifer is observed and the water breakthrough in gas wells, which is produced with rapid change as the wells are shut in blowdown technique.
   (d) But, in the case of co-production technique the wells maintain to produce at the same time due to drainage of huge amounts of water from the edge using W-4. No production

of gas is seen from W-4 throughout the whole life of the well as this well has been drilled in the water zone.

CONCLUSIONS

1. The satisfactory selection of production strategy plays a crucial role in the optimization of gas recovery and reserves.
2. The drilling of additional well of water for water production on the edge (keystone shape) may result in an optimized gas production.
3. The co-production strategy provides better results as compared to blowdown and conventional techniques in terms of produced maximum gas rate, incremental reserves and the techno-economic factors.

ACKNOWLEDGEMENT

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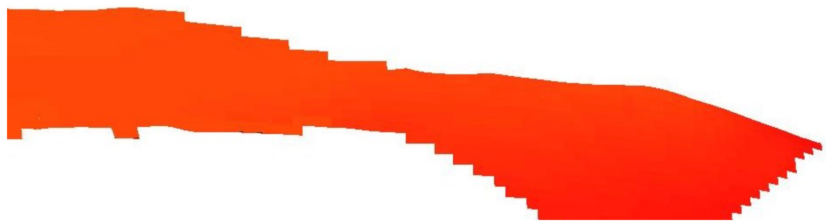
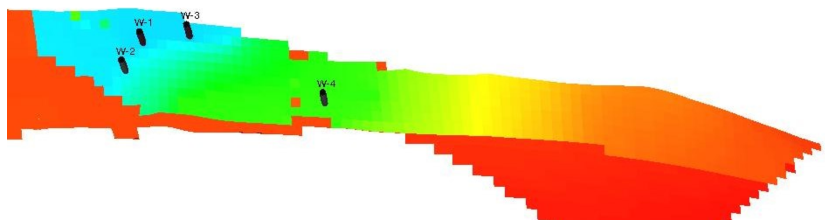
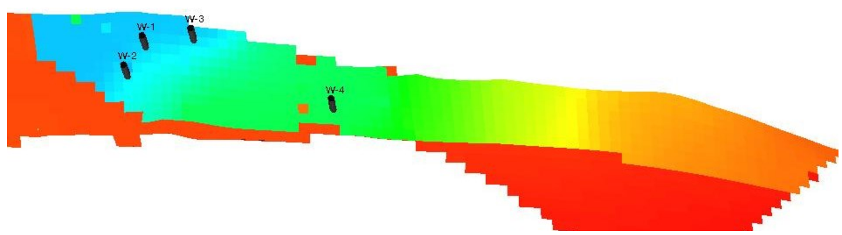


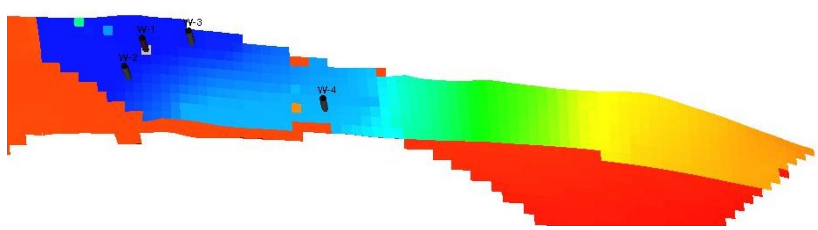
(a) Initial Pressure



(b) Final Pressure Conventional

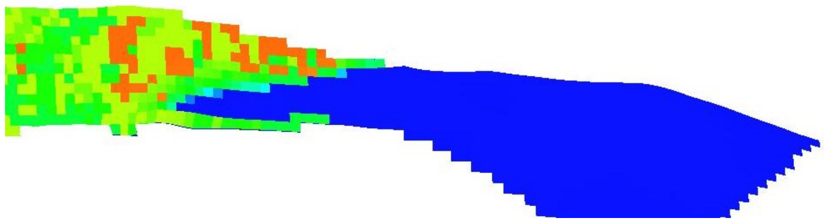


(c) Final Pressure Blowdown

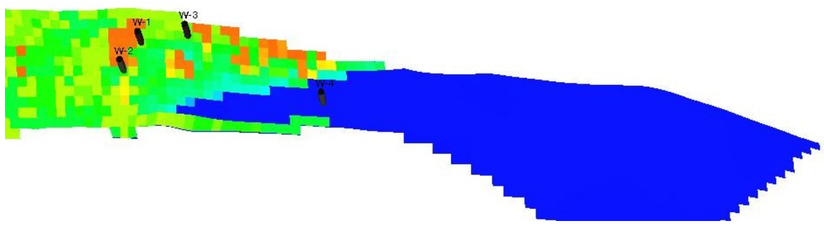


(d) Final Pressure Co-Production

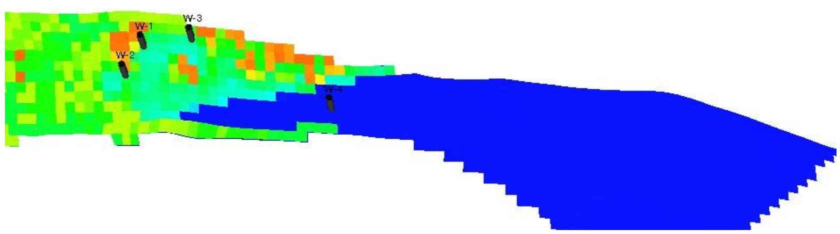
Figure 2: Pressure behavior of production techniques in all four wells.



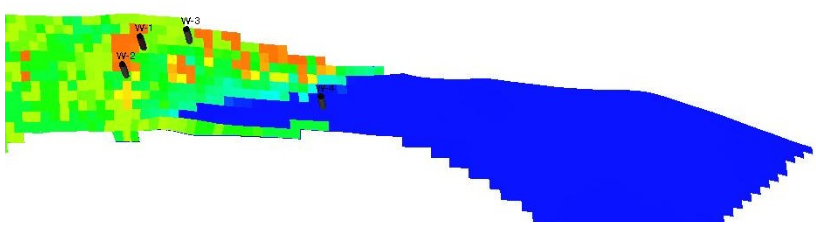
(a) Initial Gas Saturation



(b) Final Gas Saturation Conventional

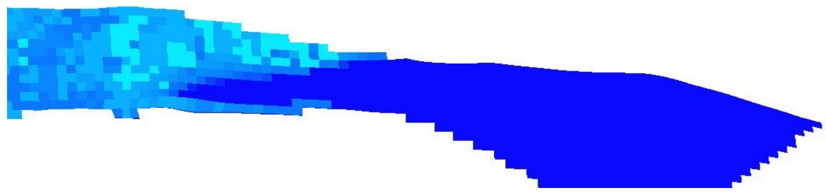


(c) Final Gas Saturation Blowdown

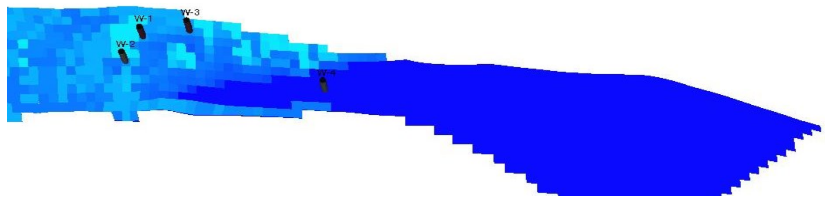


(d) Final Gas Saturation Co-Production

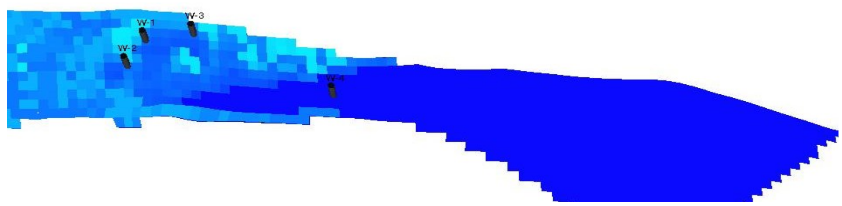
Figure 3: Saturation profile of Production techniques of all four wells.



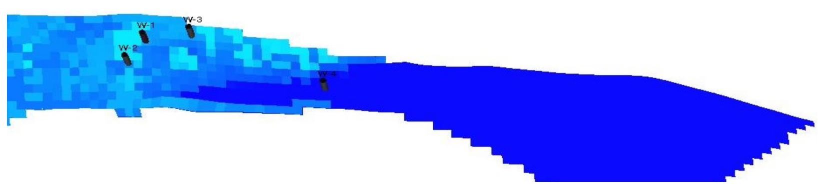
(a) Initial Water Saturation



(b) Final Water Saturation Conventional



(c) Final Water Saturation Blowdown



(d) Final Water Saturation Co-Production

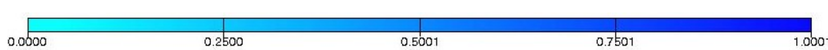


Figure 4: Water saturation profile of all techniques of all four wells.

LP GAS FRACK: AN ENERGY BREAKTHROUGH

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ABSTRACT

Shale Gas extraction is a challenging task as it is contained within the shale formations[1] that are highly porous but impermeable in nature. There are a large number of synthetic processes that are undertaken to recover the natural gas from shales, such as hydraulic fracking. Some of these processes have a harmful impact on the environment because of the chemicals that are injected during the hydraulic fracking in the wells. The pressurized gas leakages can pollute the environment. According to a recent survey, Pakistan is the 19th in term of shale reserves in the world and has 51 trillion cubic feet (TCF) of shale gas reserves. Accordingly, shale gas may be an important factor in the future growth of the country. But unfortunately, due to a number of political, technical and other factors, these reserves are still unexplored. We have accordingly written this paper to introduce and uncover a latest technique which can be an inexpensive and safe solution in order to extract these reserves according to the commercially required quantities and without any detrimental impact to the environment. The method is particularly suitable because of the factors such as water protection, very low climate impact, induced seismicity in order to minimize the risk to public health and environment. This is an advanced technique which can replace the hydraulic fracking by which we can extract these shale gas reserves in a convenient way known as 'LP GAS FRACK Method". This method enables formation of an aqueous solution of hydrocarbons which can run down through the hole. The specific properties of the solution have to be kept in consideration during the design process. This idea is taken from the distillation of crude products through which a hydrocarbons mixture (crude) produces hydrocarbons (by-products). This method is accordingly considered to be an effective method in order to utilize the hydrocarbons and produce the shale gas (which is also a hydrocarbons mixture) in a very safe and economical manner while protecting the health and environment.

Keywords: LP Gas Fracking, Shale Gas, Environmental Impact

INTRODUCTION

Shale is a type of sedimentary rock which comprises of very small clay particles sometimes called

[1] Shale is a fine-grained, clastic sedimentary rock composed of mud that is a mix of flakes of clay minerals and tiny fragments (silt-sized particles) of other minerals, especially quartz and calcite.

mud. These shales contain organic material. When broken, they are converted into oil and gas. When sediments are deposited at a depressed area (trench), organic matter is also deposited with them which is then calculated as the Total Organic Content (TOC). When this mud is buried deeply, it forms a layered rock called “Shale”. Shales have some specific properties due to which these are considered to be important resources.

Matrix permeability (capability of the fluid to flow through them) of shales is very low as compared to the conventional oil and gas reservoirs (i.e. nanodarcy in shales versus milidarcy in conventional sandstones), therefore pores are completely filled with the hydrocarbons (oil and gas) and they are not capable of flowing under normal conditions, but can slightly migrate over long periods of time. The hydrocarbons movement is slow from shales into shallower sandstone or carbonate reservoirs. Shales have been considered as a source or seal rocks rather than potential reservoirs, although large quantity of hydrocarbons remain trapped within the pores of shale. Some of the wells that produce from unconventional shale formations may be the source for other gas reservoirs. A considerable amount of gas can be confined in fracture porosity, which exists due to tectonic movements where small existing pores coalesce to enhance permeability values.

Generally, LP Gas Fracking involves the use of a working fluid [1]. Hydraulic fracturing uses an injective fluid, usually water. It takes up to an average of 60,000 gallons of water per well to frack [2]. Water is used in the process as a potent fluid as it is incompressible when exposed to the high pressures.

Propane is a gas at normal conditions (room temperature and pressure) and therefore, it has different physical behaviour as compared to water. When it is cooled and pressurized, it can exist in incompressible gel-like phase. The LP Gas fracking uses this gel instead of water to fracture the unconventional reservoirs and to provide a conduit for the hydrocarbon gasses to the surface.

Liquid propane gas fracking is a breakthrough development in the petroleum industry that can significantly boost the economy [3]. This enables the operators to use the already produced hydrocarbons to extract more hydrocarbons while reducing unnecessary infrastructure [4]. When liquid propane gas is mixed with the desired chemicals, it provides an unchangeable viscosity, so there is no requirement to use any CO_2 or N_2, in any special venting and cool down system. LPG produced is stored in a vessel and kept at an ambient pressure. Its usage reduces the CO_2 emissions. As this has half the specific gravity of water, the trucking investments get reduced by up to 90%. In the past, since fifty years, LPG was used for conventional reservoirs but in this case, it can be used as a stimulation fluid to fracture the unconventional reservoirs. For instance, it was used for the stimulation oil wells stimulation and tight gas sands to improve the recovery efficiencies.

2. LITERATURE REVIEW

R. S. Lestz, a research engineer, during an offshoot work at Chevron in 1990’s experimented with the nitrogen and carbon dioxide and came up with a brilliant idea to enhance the fracturing process [3] . He accordingly suggested the idea of LPG gel based frack process and acquired its patent. Safety and equipment procedures were developed during the process to cope with the volatile fluid (as it is flammable in nature and can pose process safety risks) including a vapor and pressure sensor system, infrared cameras, remote equipment operation and emergency gas release flares [3] . After

this development, the process was rapidly deployed at a number of locations to reap its extensive benefits. LPG technology was used to frack its first well in 2008. And afterwards, the GASFRACK Company has performed 1863 fractures of 857 locations as of spring 2013 [8].

2.1 HISTORY OF SHALE

Historically, Pakistan has not made any significant use of this technology so far due to a lack of attention, however still there is a long way to go for shale gas recovery in the country and this technology can be implemented. In April 2011, EIA reported that there were 206 TCF reserves present in the lower Indus Basin, of which 51 TCFs were technically recoverable. It is shown in the shale resource map (figure 1) that the reserves that are trapped within the shale reservoirs are located in Lower Indus Basin particularly in Rani Kot and Sembar region. In 2015, USAID confirmed the presence of 10159 TCF of shale gas reserves in Pakistan which are not explored till today. The availability of huge reserves can possibly lessen Pakistan's reliance on the imports and beat the present energy challenges. This would provide support to the industrial economy. However, this would only become possible when an uncompromized priority will be given to the investments required to develop the energy areas throughout the country. In Pakistan, 70% area is full of shale reserves now and one can expect if these reserves are utilized, there will be a massively positive effect on country's economy.

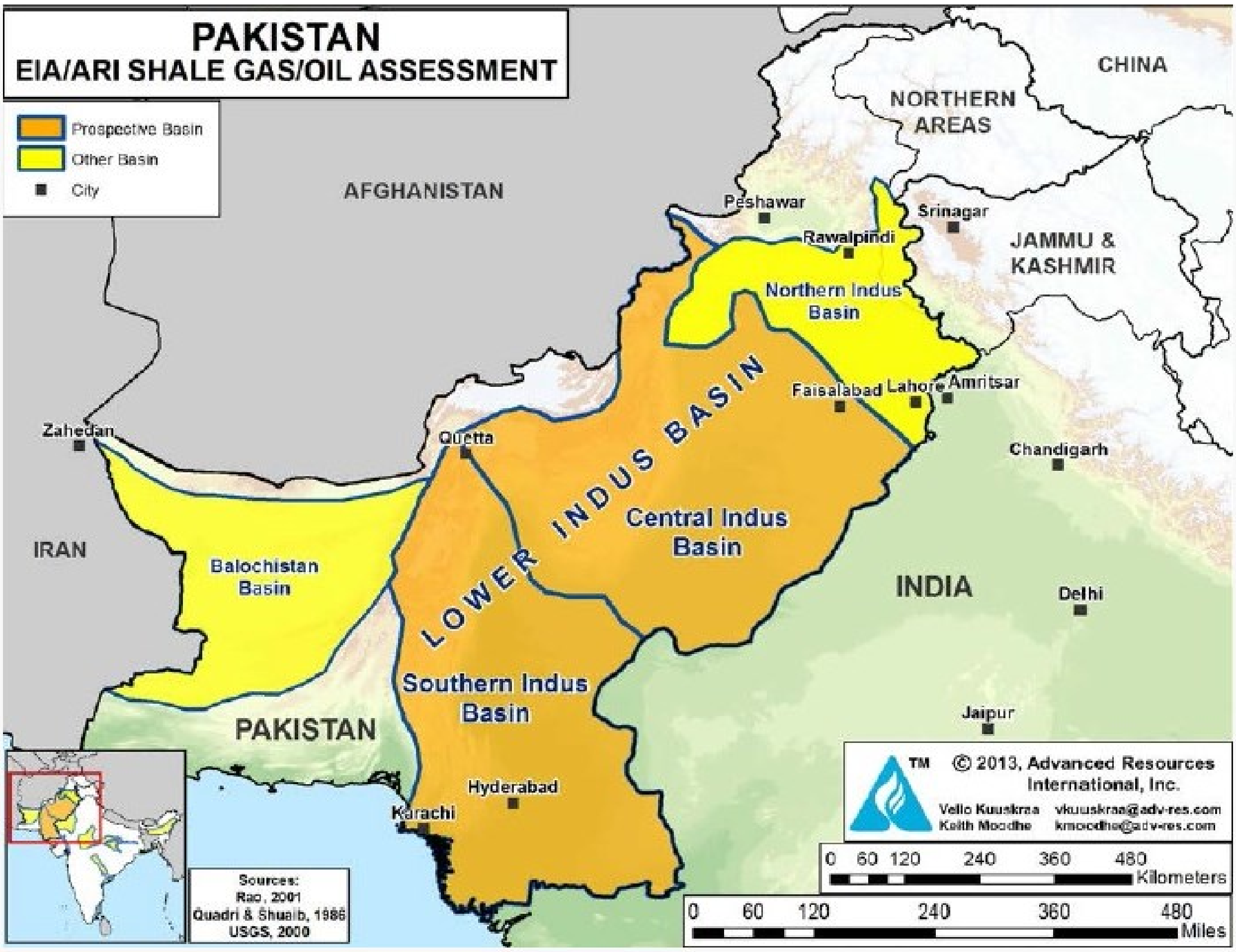

Figure 1. Shale Resource Map

The study suggests that development of the unconventional gas would be adequate to accomplish the demand of natural gas for almost 45 years at the rate of 8 MMMSCF per year and achievement in recovery efficiency of oil and gas will generate 7, 50,000 jobs throughout the country[10].

3. PROCESS

Initially, LPG is gelled before the fracturing to permit better transport of proppant into the fracture. When fracturing, the LPG remains liquid, but after completing the process it goes into solution with the reservoir gas.

In this method, the mixtures of light hydrocarbons are used (like propane, butane, and pentane) which have low surface tensions, viscosity, density and solubility within hydrocarbon reservoirs and have high Reid Vapour Pressure (HRVP). These characteristics are useful to develop the efficient fracture length and enhance the migration of hydrocarbons through the reservoir in the well.

The molecular formula of LPF is C_3H_8.It minimize clean up and enhance the GASFRAC's recovery economics. The injected LPG mixes with reservoir fluid and flows back with the production fluid and we can obtain 90 – 100% of LPG recovery on processing facility.

3.1. RATIONALE

Liquid propane is an appropriate fracturing fluid as its viscosity is less than water. Shale formations behave sensitively when the water interacts; therefore using LPG would avoid this problem. The Gas Frack LPG gel possesses low surface tension, low viscosity, low density, and is soluble with the reservoir fluids. These properties lead to additional effectual fracture lengths and higher production rate from the well. Another advantage is the ability to evenly distribute proppant. The fracturing fluids are entirely recovered within days of stimulation, which yields greater economic and environmental advantages by reducing clean-up, waste disposal, and post-job truck traffic (Gas Frack 2013).

Water	**Quantity**	**Liquid Petroleum Gas**	**Quantity**
Specific gravity	1.02	specific gravity	0.51
Viscosity	0.66 cps @ (104F)	Viscosity	0.78 cps @ (103F)
Surface Tension	72 dynes/cm	Surface Tension	7.6 dynes/cm
Potentially Damaging-Reactive with clays/salts		Non-Damaging- Inert with the formation clays/salts	

Table 1: Comparison between Water and LPG

SURFACE FACILITIES:

The key equipment for effective LPG Fracking is as follows:

Storage Tank: Boost pump and nitrogen pressurization is used. The storage tanks store the LPG and LPG feed which is sent to the specialized sand blenders. To ensure safety, a pressurized nitrogen blanket is used for all storage tanks.

Sand Blender: This facility is pressurized with the nitrogen to purge and proppant is preloaded .A controller is installed which measures the proppant into the gelled LPG, creating LPG sand loaded slurry to stimulate the reservoir.

Pumping Units: These are the high-pressure pumping units that pump the slurry down the hole at specified surface pressures. Propane fracking needs specialized equipment (to perform operation under the pressures and low temperatures to keep the liquid in liquid state) and the safety systems (as propane is flammable and in order to handle emergency situations).

3. FACTS AND FIGURES

This method has already been utilized by Gasfrack Energy Services, a Canadian Company in Alberta, by using propane as it mixes well into formation hydrocarbon and improves performance without using water [9]. It uses a proxy for water to switch the sand/ceramics required to fracture the shale rock.

LPG is a flammable mixture and obviously, it can burn, therefore GASFRACK has proposed a closed system with zero oxygen by utilizing a specific equipment that protects the workers and requires only a minimum flaring that can be diminished to zero when appropriate recapturing facilities are installed [2] . This gives a boost to the oil and gas recovery and leads to a long-lasting production by recovering 100% of fracturing agent. Recovered LPG can be reused and resold.Propane (C_3H_8) is a hydrocarbon that wouldn't alter the rock formation during the process, as it has a low viscosity, low surface tension, and low density along with solubility within reservoir hydrocarbons. Due to this, it initiates an excellent fracture lengths giving greater and long term production.

The sand or proppant can be distributed while pumping; hence it decreases the proppant settling in the inconvenient areas of the formation. About 1300 wells have been fracked in Canada, however, it has to be noted that the technique was typically planned to develop the performance of low pressure wells. LPG frack saves billions of gallons of potable water that used be required in the hydraulic fracturing (as fracking a well has required 3 to 12 million gallons of water).

Figure 2 provides a visual description of comparative benefits of this system.

4.1. ENVIRONMENTAL CONCERNS

LP Gas has a much positive role in the fracturing process as compared to the hydraulic fracturing, during which huge quantity of water is used which is then disposed to the impoundments and becomes a potential sources of water pollution. Environmentally, LP Fracking is highly practical as it resolves the relevant environmental issues as well as increases the oil and gas recovery efficiency by 20-30%. It eliminates the problem of getting used water as by-product which is very toxic and a major source of pollution. LPG returns at the surface are captured and recycled.

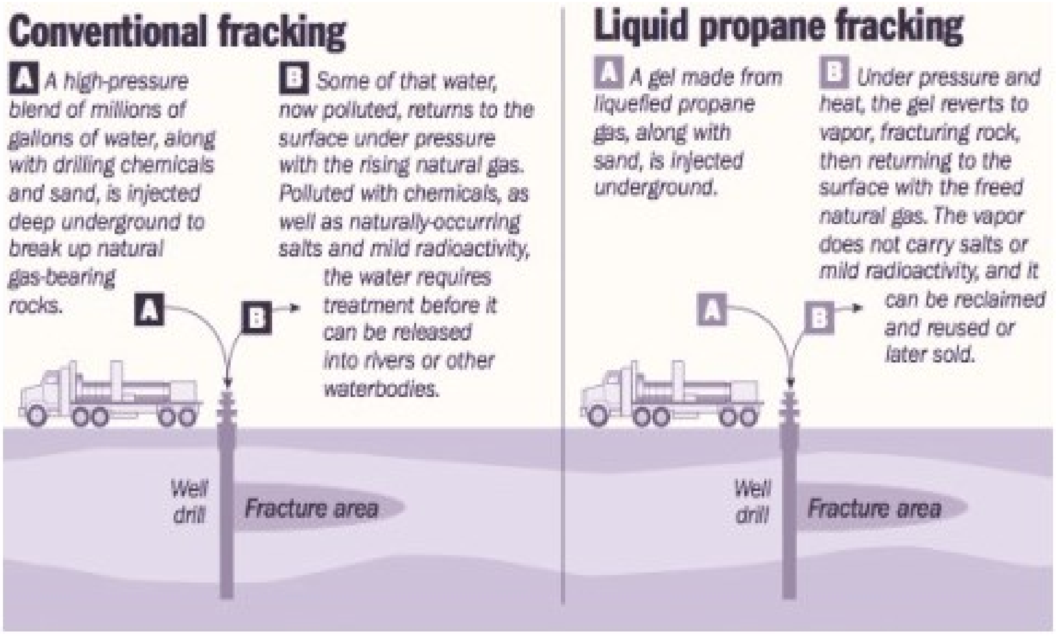

Figure 2. Benefits of LPG Fracking over Hydraulic Fracturing

CONCLUSIONS

It is concluded that LP gas fracking can be a reliable and effective method due to following important factors:

- It has low capital cost,
- It doesn't require the use of water (only LPG gel is pumped down the well along with sand/ceramics),
- LPG gel gives desired properties i.e. low viscosity, low specific gravity, and low surface tension as compared to water which results in large fracture lengths.
- While production is in progress from the reservoir to the surface, the LPG in liquid state mixes with the production fluid (gas) and it is recaptured and reutilized for the same purpose.
- This process reduces the number of equipment required for the process and accordingly saves time, capital and maintenance expenses.
- It doesn't create water pollution as there is no water to be disposed off.
- It doesn't have an adverse effect on the health and environment as no massive shocks are generated from the earth that may become a cause for environmental disorders.

NOMENCLATURE

LPG= Liquid propane gas,

TOC= Total Organic Content,

TCF= Trillion Cubic Feet,

USGS= United States Geological Survey,

EIA= Energy Information Administration,

USAID= United States Agency for International Development,

MMMSCF= Billion Standard Cubic Feet.

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BOOK REVIEW

CASE STUDY RESEARCH – DESIGN AND METHODS

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Case Study Research: Design and Methods

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Author:
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Introduction to author:

Robert Yin (b. 1941) is a renowned figure among the qualitative and case study researcher. Yin's diverse qualifications span over the disciplines of history and cognitive science. He has authored more than a hundred books and articles. Among them, his trademark is his works on qualitative research methods (including his famous book 'Qualitative research from start to finish') and case study methodology (including the book being reviewed here and other books on the topic). In addition to his individual research work, Yin is also the present of COSMOS Corporation, a firm that has provided research services to dozens of public and private organizations.

Book Review:

Case study research methodology is a very widely applied approach which encompasses multiple disciplines and professions including technical and engineering sciences. Numerous books are available that attempt to explain the definitions, types and approaches adopted for this type of study, however, 'Case study research: Design and methods' by Yin is considered to be one of the most comprehensive and well-structured books on the topic. There would hardly any renowned library or university where this book is not read or referenced. It is referenced by thousands of academics and researchers from around the globe. Its step-by-step approach and clear explanation of key concepts make it a very handy resource. Yin's comprehensive methodological articulation encompasses all facets of the case study method ranging from the problem definition, design, and

data collection phases, to data analysis and composition and reporting. Based on his own experiences and a wide-ranging review of case studies conducted by other researcher, Yin points out their application in a number of industries and disciplines.

Number of chapters in the book remain the same as its previous edition. However, Yin explains in the preface that the fifth edition has expanded in terms of its breadth and depth. This claim is justified in the light of information provided in the appendices and the tutorials added at the end of each chapter. In addition to this, a lot of text and formatting has been revised making it more convenient for the researchers to follow the almost step-by-step guidelines present in the book.

Case study research, though highly popular, has seen significant level of controversy and debate. Yin has tried to answer five such objections and concerns in chapter one (pp. 3-26) and provided how and where the case study research can be effectively deployed. In certain situations, Yin believes, it can even yield better results as compared to other methodologies. Those who are yet to decide the methodology for their research would find this chapter to be very useful as it lays out the clear criteria (figure 1.2) that the researchers can use to determine if case study can be productive for the type of problem they are trying to solve or not. Yin has also provided references to some useful case studies in figure 1.1 which can be useful examples (from four disciplines and eight professions) to consider before and during the study. It is also important to note here that case study can be of different types. Yin has categories case studies into three types include explanatory, exploratory, and descriptive types, each being different from the other in terms of objectives and methodological approach.

In chapter 2 (pp. 27-70), focusses on the overall design of case studies, their key components, and quality assurance aspects. Yin proposed five key components that are considered especially important in terms of case study design. This includes research questions, propositions, units of analysis, logic for linking data to the propositions, and the criteria for interpreting the findings. He then explains each of these components and provides examples. Yin has provided examples of 8 types cases that the case studies can be based upon (figure 2.1). He also delineates the conditions when some of these steps may not be applicable for legitimate reasons. For example, in the exploratory research, propositions would not yield any benefit as the purpose is only to explore and know more about a case or a situation. The discussion than uncovers the ties between the contents in this chapter and the following ones. Yin touches another hot topic in this chapter in relation to case studies, generalization, and explains how and when the information from the case studies can be generalized.

After this explanation about the overall design and linkage of various components, Yin introduces the readers to initial steps in the process in chapter 3 (pp. 71-102). The discussion focusses on training oneself to conduct the case study research, identifying suitable cases, and formulating the protocol (figure 3.2). Each stage in the protocol is then elaborated separately under four sections. The chapter concludes with a discussion on screening the candidates for the study and conducting the pilot study in order to ensure smooth conduct of the main research.

Chapter 4 (pp. 103-132), logically, moves to the data collection processes. Yin provides six key sources recommended for use within the case study research which include analysis of documentation, archival records, interviews, direct observations, participant observations, and

physical artefacts. This chapter also clarifies a common misconception. Some people think that the case studies are only qualitative in nature. Though the six methods recommended by Yin seem to support this assertion, he separately mentions that the data for case studies can come from qualitative as well as quantitative source. Yin has also provided the principles that are recommended to be followed when collecting data for the case studies. This includes using multiple sources of data for triangulation purposes, maintaining case study database for tracking and evidentiary purposes, maintaining chain of evidences for reliability purposes, and exercising caution when using electronic sources to ensure that the research stays on track.

The key focus in chapter 5 (pp. 133-176) is the data analysis. The discussion focusses on organization and presentation of data for analysis in different manners, development of an overall analytical strategy, methods for finding patterns and insights from the data, use of five specific analysis techniques (including pattern matching, explanation building, time-series analysis, logic models, and cross-case synthesis), extracting explanations and questioning them in the presence of rival explanations. Yin has provided nine types of rival explanation (figure 5.1) that can be considered during the analysis.

The last chapter in the book, chapter six (pp. 177-208), presents an overview of the reporting process. The encompasses defining the audience for the case study report, preparing materials that the report would be comprised of, ensuring provision of relevant evidence as required, and ensuring adequate review and good presentation of the report. This, though considered less important by some researchers, is a very important component of the overall case study research process. Yin has provided various structures (figure 6.1) that can improve the weight and presentation of the case study findings. This includes linear analytic, comparative, chronological, theory-building, suspense, and un-sequenced styles of reporting findings.

In the end, Yin has included some useful appendices. Appendix A and B present notes on use of case study in the fields of psychology and evaluation, respectively. Appendix C provides a list of case studies referenced in the text. This can be a very useful armoury for young researchers and academics.

Having benefitted from this book personally, I strongly recommend case study researchers to use this book as their day to day reference. Its comprehensive and step-by-step nature of description, significantly enhances its usability and usefulness. However, it needs to be kept in mind that this is not the only way to look at the case studies. The texts and articles put forth by Stake (1994, 1995, 2013), Meriam (1998, 2009), Thomas (2010), Johansson (2003), Eisenhardt (1989) and other researchers provide a useful alternate view about this methodology and studying those works in conjunction with this book may prove to be even more productive.

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